

WHAT IS CLAIMED IS:

1. A method for locating a low contrast movable object coupled mechanically to a marker object in a series of image frames that include images of the low contrast object and the marker object,

said method comprising:

locating the marker object in a first selected frame of the series of image frames;

selecting a patch of the first selected frame as a template of the marker object;

utilizing the template of the marker object to estimate a location of the marker object in a second selected frame of the series of image frames;

registering the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame; and

fusing the registered first selected frame and the second selected frame to thereby enhance the contrast of the low contrast moveable object.

2. A method in accordance with Claim 1 wherein said registering the second selected frame with the first selected frame comprises estimating a motion of the marker object between the first selected frame and the second selected frame.

3. A method in accordance with Claim 1 further comprising removing a background from the first selected frame prior to selecting the template of the marker object in the first selected frame.

4. A method in accordance with Claim 1 further comprising removing a background from the second selected frame prior to utilizing the template of the marker object from the first selected frame to estimate the location of the marker object in the second selected frame.

5. A method in accordance with Claim 1 wherein the second selected frame is a frame subsequent to the first selected frame, and said method further comprises utilizing the second selected frame to modify the template of the marker object.

6. A method in accordance with Claim 5 wherein said utilizing the second selected frame to modify the template of the marker object comprises utilizing frames acquired both before and after the second selected frame to modify the template of the marker object.

7. A method in accordance with Claim 1 wherein the first selected frame and the second selected frame comprise intensities of a first image and of a second image, respectively, stored in a computer memory.

8. A method in accordance with Claim 1 wherein the first selected frame and the second selected frame comprise logarithms of intensities of a first image and of a second image, respectively, stored in a computer memory.

9. A method in accordance with Claim 1 further comprising removing a background from the first selected image and from the second selected image.

10.
~~10.~~ A method in accordance with Claim 9 wherein said removing a background comprises utilizing a local median intensity to remove the background.

11.
~~11.~~ A method in accordance with Claim 9 wherein said removing a background comprises utilizing a linear filter.

12.
~~12.~~ A method in accordance with Claim 9 wherein said removing a background comprises interpolating the background of a coarser scale image in a Laplacian Pyramid.

13.
~~13.~~ A method in accordance with Claim 1 further comprising taking a square root of frame intensities of the first selected frame and the second selected frame, followed by removing a background from the first selected frame and from the second selected frame.

14.

15. A method in accordance with Claim 1 wherein said locating the marker object in a first selected frame comprises signaling a location of the marker object utilizing a mouse click signal.

15.

16. A method in accordance with Claim 1 wherein said locating the marker object in a first selected frame comprises utilizing a matched filter to locate a point at which the first selected frame produces a maximum response to the matched filter.

16.

17. A method in accordance with Claim 1 wherein said utilizing the template of the marker object to estimate a location of the marker object in a second selected frame comprises correlating the template of the marker object with the second selected frame in either a spatial or a Fourier domain.

17.

18. A method in accordance with Claim 1 wherein said utilizing the template of the marker object to estimate a location of the marker object in a second selected frame further comprises utilizing prior marker object locations to estimate the location of the marker object in the second selected frame.

18.

19. A method in accordance with Claim 1 wherein said utilizing the template of the marker object to estimate a location of the marker object in a second selected frame of the series of image frames further comprises utilizing a Kalman filter to estimate motion of the marker object.

19.

20. A method in accordance with Claim 19 further comprising utilizing a statistic of a mean free path of the marker object to determine how much modeled motion to utilize and how much data-driven motion to utilize in the Kalman filter.

20.

21. A method in accordance with Claim 19 further comprising estimating a confidence interval on a location of the marker object.

21.

22. A method in accordance with Claim 1 wherein said utilizing the template of the marker object to estimate a location of the marker object in a second

selected frame of the series of image frames comprises locating two marker objects and fitting a portion of a connecting member between the two marker objects with a spline.

23. 23. A method in accordance with Claim 1 wherein said registering the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame comprises regriding.

24. 24. A method in accordance with Claim 1 wherein said registering the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame comprises a translation and a rotation.

25. 25. A method in accordance with Claim 1 wherein said registering the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame further comprises a warping.

26. 26. A method in accordance with Claim 1 wherein said fusing the registered first selected frame and the second selected frame to thereby enhance the contrast of the low contrast moveable object comprises pixelwise averaging.

27. 27. A method for locating a stent on a guidewire in a series of x-ray image frames of a patient utilizing one or more marker objects on the guidewire indicative of a location of the stent,

said method comprising:

locating the marker object in a first selected frame of the series of image frames;

selecting a patch of the first selected frame as a template of the marker object;

utilizing the template of the marker object to estimate a location of the marker object in a second selected frame of the series of image frames;

registering the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame; and

fusing the registered first selected frame and the second selected frame to thereby enhance the contrast of the stent in the second selected frame.

27 28. A method in accordance with Claim *27* wherein said registering the second selected frame with the first selected frame comprises estimating a motion of the marker object between the first selected frame and the second selected frame.

28 29. A method in accordance with Claim *27* further comprising removing an anatomical background from the first selected frame prior to selecting the template of the marker object in the first selected frame.

29 30. A method in accordance with Claim *27* further comprising removing an anatomical background of the patient from the second selected frame prior to utilizing the template of the marker object from the first selected frame to estimate the location of the marker object in the second selected frame.

30 31. A method in accordance with Claim *27* wherein the second selected frame is a frame subsequent to the first selected frame, and said method further comprises utilizing the second selected frame to modify the template of the marker object.

31 32. A method in accordance with Claim *31* wherein said utilizing the second selected frame to modify the template of the marker object comprises utilizing frames acquired both before and after the second selected frame to modify the template of the marker object.

32 33. A method in accordance with Claim *27* further comprising removing an anatomical background from the first selected image and from the second selected image.

33.

34. A method in accordance with Claim 33 wherein said removing an anatomical background comprises utilizing a local median intensity to remove the background.

34.

35. A method in accordance with Claim 33 wherein said removing an anatomical background comprises utilizing a linear filter.

35.

36. A method in accordance with Claim 33 wherein said removing an anatomical background comprises interpolating the background of a coarser scale image in a Laplacian Pyramid.

36.

37. A method in accordance with Claim 27 wherein said locating the marker object in a first selected frame comprises utilizing a matched filter to locate a point at which the first selected frame produces a maximum response to the matched filter.

37.

38. A method in accordance with Claim 27 wherein said utilizing the template of the marker object to estimate a location of the marker object in a second selected frame comprises correlating the template of the marker object with the second selected frame in either a spatial or a Fourier domain.

38.

39. A method in accordance with Claim 27 wherein said utilizing the template of the marker object to estimate a location of the marker object in a second selected frame of the series of image frames comprises locating two marker objects and fitting a portion of a connecting member between the two marker objects with a spline.

39.

40. A method in accordance with Claim 27 wherein said registering the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame comprises a translation and a rotation.

40.

41. A method in accordance with Claim 27 wherein the second selected image is an x-ray image acquired later than the first selected image, and

further comprising attempting to deploy the stent and utilizing the enhanced contrast of the stent to determine whether the stent has been successfully deployed.

⁴¹
~~42~~. A method in accordance with Claim ⁴⁰~~41~~ performed without injection of a contrast-enhancing bolus after the deployment of the stent.

⁴²
~~43~~. An apparatus for tracking a motion of an object, said apparatus comprising a computer configured to process a series of image frames, and a display device,

said apparatus configured to:

RUE
1.12.12
locate the marker object in a first selected frame of the series of image frames;

select a patch of the first selected frame as a template of the marker object;

utilize the template of the marker object to estimate a location of the marker object in a second selected frame of the series of image frames;

register the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame; and

fuse the registered first selected frame and the second selected frame to thereby enhance the contrast of the low contrast moveable object.

⁴³
~~44~~. An apparatus in accordance with Claim ⁴²~~43~~ wherein to register the second selected frame with the first selected frame, said apparatus is configured to estimate a motion of the marker object between the first selected frame and the second selected frame.

⁴⁴
~~45~~. An apparatus in accordance with Claim ⁴³~~44~~ further configured to remove a background from the first selected frame prior to selecting the template of the marker object in the first selected frame.

45. 46. An apparatus in accordance with Claim 43 further configured to remove a background from the second selected frame prior to utilizing the template of the marker object from the first selected frame to estimate the location of the marker object in the second selected frame.

46. 47. An apparatus in accordance with Claim 43 wherein the second selected frame is a frame subsequent to the first selected frame, and said apparatus is further configured to utilize the second selected frame to modify the template of the marker object.

47. 48. An apparatus in accordance with Claim 43 wherein to utilize the second selected frame to modify the template of the marker object, said apparatus is configured to utilize frames acquired both before and after the second selected frame to modify the template of the marker object.

2210
1.124 48. 49. An apparatus in accordance with Claim 43 further comprising a memory, and wherein the first selected frame and the second selected frame comprise intensities of a first image and of a second image, respectively, stored in a computer memory.

49. 50. An apparatus in accordance with Claim 43 further comprising a memory, and wherein the first selected frame and the second selected frame comprise logarithms of intensities of a first image and of a second image, respectively, stored in the memory.

50. 51. An apparatus in accordance with Claim 51 further configured to remove a background from the first selected image and from the second selected image.

51. 52. An apparatus in accordance with Claim 51 wherein to remove the background, said apparatus is configured to utilize a local median intensity to remove the background.

~~53~~. An apparatus in accordance with Claim ~~51~~ wherein to remove the background, said apparatus is configured to utilize a linear filter.

~~54~~. An apparatus in accordance with Claim ~~51~~ wherein to remove the background, said apparatus is configured to interpolate the background of a coarser scale image in a Laplacian Pyramid.

~~55~~. An apparatus in accordance with Claim ~~43~~ further configured to take a square root of frame intensities of the first selected frame and the second selected frame, and subsequently to remove a background from the first selected frame and from the second selected frame.

~~56~~. An apparatus in accordance with Claim ~~43~~ wherein to locate the marker object in the first selected frame, said apparatus is configured to receive an indication of a location of the marker object signaled by a mouse click.

~~57~~. An apparatus in accordance with Claim ~~43~~ wherein to locate the marker object in a first selected frame, said apparatus is configured to utilize a matched filter to locate a point at which the first selected frame produces a maximum response to the matched filter.

~~58~~. An apparatus in accordance with Claim ~~43~~ wherein to utilizing the template of the marker object to estimate a location of the marker object in a second selected frame, said apparatus is configured to correlate the template of the marker object with the second selected frame in either a spatial or a Fourier domain.

~~59~~. An apparatus in accordance with Claim ~~43~~ wherein to utilize the template of the marker object to estimate a location of the marker object in a second selected frame, said apparatus is configured to utilize prior marker object locations to estimate the location of the marker object in the second selected frame.

~~60~~. An apparatus in accordance with Claim ~~43~~ wherein to utilize the template of the marker object to estimate a location of the marker object in a second

selected frame of the series of image frames, said apparatus is further configured to utilize a Kalman filter to estimate motion of the marker object.

61. An apparatus in accordance with Claim 60 further configured to utilize a statistic of a mean free path of the marker object to determine how much modeled motion to utilize and how much data-driven motion to utilize in the Kalman filter.

62. An apparatus in accordance with Claim 60 further configured to estimate a confidence interval on a location of the marker object.

63. An apparatus in accordance with Claim 62 wherein to utilize the template of the marker object to estimate a location of the marker object in a second selected frame of the series of image frames, said apparatus is configured to locate two marker objects and fit a portion of a connecting member between the two marker objects with a spline.

64. An apparatus in accordance with Claim 43 wherein to register the second selected frame with the first selected frame utilizing the estimated location of the marker object in the second selected frame, said apparatus is configured to translate and to rotate said second selected frame.

65. An apparatus in accordance with Claim 43 configured to pixelwise average the registered first selected frame and the second selected frame to thereby enhance the contrast of the low contrast moveable object.

66. An apparatus in accordance with Claim 43 wherein said apparatus further comprises an x-ray imager, and said image frames comprise x-ray images.